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(54) Liquid crystal color display device

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Specification

1. Title of the Invention

Liquid crystal color display device

2. Scope of Claims

1.) A liquid crystal color display device comprising:

two substrates provided with a transparent electrode on which an orientation treatment is performed;

dichroic dyes and nematic liquid crystals or dichroic nematic liquid crystals sealed between the substrates; and

a reflector,

characterized in that comb-shaped transparent electrodes are formed on at least one substrate as for the transparent electrode;

the liquid crystal molecules are orientated perpendicular to one substrate surface and parallel to another substrate surface; and

an electric field is impressed between the comb-shaped transparent electrodes to change a molecular arrangement and to display information.

2.) A liquid crystal color display device comprising:

two substrates provided with a transparent electrode on which an orientation treatment is performed;

dichroic dyes and nematic liquid crystals or dichroic nematic liquid crystals sealed between the substrates; and

a reflector,

characterized in that comb-shaped transparent electrodes are formed on at least one substrate as for the transparent electrode;

the liquid crystal molecules are orientated perpendicular to one substrate surface and parallel to another substrate surface;

a polarizing plate is provided between the substrate and the reflector; and

an electric field is impressed between the comb-shaped transparent electrodes to change a molecular arrangement and to display information.

3. Detailed Description of the Invention

The present invention relates to a liquid crystal color display device in which an electro-optical effect of a liquid crystal is applied and color display is performed.

A liquid crystal display device is known in which a pair of comb-shaped electrodes as shown in FIG. 1a is formed on one substrate which is opposed to another substrate as shown in FIG. 1b and liquid crystals are sealed between the two substrates. Namely, in R. A. Soref Proc IEEE the December Issue for 1974, pp. 1710 - 1711, a liquid crystal display device comprising substrates 1 and 5, a comb-shaped electrode 2, a spacer 3 and a liquid crystal 4 is published. In this liquid crystal display device, nematic liquid crystals of a perpendicular orientation or a twisted orientation are used and only black and white can be displayed. It has not yet been put in practical use since color cannot be displayed.

The present invention provides a liquid crystal display device in which the comb-shaped electrode is used and color display is possible.

In the present invention, a pair of comb-shaped transparent electrodes is formed on at least one substrate, an orientation treatment is performed on two substrates, and dichroic dyes and nematic liquid crystals or dichroic nematic liquid crystals are sealed between the substrates so as to be orientated perpendicular to one substrate surface and parallel to another substrate surface. The invention is characterized in that an electric field is impressed between the comb-shaped electrodes to change a molecular arrangement thereof so that optical property is changed and information is displayed.

Subsequently, an embodiment and a principle are described with reference to drawings. FIG. 2 shows one embodiment. It is a cross-sectional view that is at right angle to a longitudinal direction of the comb-shaped electrodes. Reference numeral 6 is a liquid crystal molecule, 7 is a dichroic dye molecule, 8 is a polarizing plate and 9 is a reflector. A polarizing direction of the polarizing plate is parallel to a paper surface. An orientation treatment is performed on the two substrate surfaces so that the liquid crystal molecules are orientated perpendicular to the substrate on a surface of a top substrate 1 and parallel to the substrate on a surface of a bottom substrate 5. Then, as shown in FIG. 2, a molecular arrangement in which tilt angles of molecules are

gradually changed can be obtained. At this time, the dichroic dye molecules also have the same orientation as the liquid crystal molecules. On the bottom substrate surface, a long axis of the liquid crystal molecule is at right angle to the longitudinal direction of the comb-shaped electrodes. In FIG. 2, large arrows 31 and 32 indicate a traveling direction of light, and arrows 10, 11, 12, 13, 14 and 15 in circles indicate a polarizing direction of light. The arrows 10 in which arrows in a lateral direction mean parallel polarization to the paper surface and arrows in a vertical direction mean perpendicular polarization to the paper surface indicate a polarizing direction of incident light which is polarized in various directions. Reference numeral 11 denotes a polarizing direction of light which has once passed a cell, 12 denotes a polarizing direction of light which has further passed the polarizing plate 8, 13 denotes a polarizing direction of light which has been further reflected by the reflector 9, 14 denotes a polarizing direction of light which has further passed the polarizing plate 8 and 15 denotes a polarizing direction of light which has further passed the cell, respectively. In the following drawings in which a circle having only a point at the center indicates that light intensity is zero, arrows in circles 10, 11, 12, 13, 14 and 15 denote a polarizing direction of light in the same position respectively as shown in FIG. 2. The dichroic dye molecules 7 absorb light that is polarized parallel to a molecular long axis, but do not absorb light that is polarized perpendicular to the molecular long axis. As indicated by the arrows 10, the incident light is polarized in all directions.

Polarized components of the incident light that is perpendicular to the paper surface are not absorbed by the dichroic dyes and reach the polarizing plate 8, however, the polarizing direction is orthogonal, and thus, they do not reach the reflector 9 and are not reflected from the liquid crystal cell. On the contrary, a part of light of a wavelength that is close to an absorption wavelength of the dye of the polarized components that are parallel to the paper surface is absorbed by the dye molecules. As shown in FIG. 2, since the tilt angles are gradually changed in the dye molecules, an absorption amount of light is smaller than that in the case where the dye molecules are arranged parallel to the substrate. A part of the light is absorbed by the dyes and is transmitted through the polarizing plate 8 whose polarizing direction corresponds to

that of the light, reflected by the reflector 9 and transmitted again through the polarizing plate 8. It passes through the liquid crystal layer again and is absorbed by the dyes again at the same time. Light of the absorption wavelength of the dye is lacking in a spectrum of the light that returns from the liquid crystal cell. Therefore, the liquid crystal cell looks slightly colored.

FIG. 3 shows a case where a voltage is applied between the comb-shaped electrodes of the liquid crystal cell in FIG. 2. A voltage is applied between the comb-shaped electrodes by the method as shown in FIG. 1a.

Then, a line of electric force is generated as shown by 16 of FIG. 3a. FIG. 3a shows a case where P type nematic liquid crystals or P type dichroic nematic liquid crystals are used. In a P type liquid crystal molecule 6, a dielectric constant in a molecular long axis direction is higher than that in a molecular minor axis direction; thus, the molecular long axis is orientated parallel to the line of electric force 16 as shown in FIG. 3a. The dichroic dye molecules 7 over the comb-shaped electrodes are rearranged parallel to the substrates 1 and 5 together with the liquid crystal molecules 6 which are located around. Then, light absorption by the dyes 7 is increased so that most of the polarized components of the absorption wavelength of the dye that are parallel to the paper surface as indicated by arrows in a lateral direction in the circles 10, 11, 12, 13, 14 and 15 are absorbed by the dyes. Since light of the absorption wavelength of the dye is lacking in a spectrum of reflected light from the liquid crystal cell, the reflected light looks strongly colored. As a result, a portion 17 with the comb-shaped electrodes marked with diagonal lines in FIG. 3b is strongly colored and can be distinguished from a portion 18 without the comb-shaped electrodes which is colored weakly, and thus information can be displayed.

FIG. 4a shows a case where n type nematic liquid crystals or n type dichroic nematic liquid crystals are used. The polarizing plate 8 polarizes light to the paper surface direction. When a voltage is applied between the comb-shaped electrodes, a line of electric force is generated and n type liquid crystal molecules are rearranged as shown in the figure. The dye molecules 7 are also rearranged perpendicular to the substrates 1 and 5 as the liquid crystal molecules 6. All the incident light is polarized

to the molecular minor axis direction so that light is not absorbed by the dyes. Therefore, as shown in FIG. 4b, a portion 19 with the comb-shaped electrode is not colored and can be distinguished from a portion 20 without the comb-shaped electrode which is colored weakly, and thus, information can be displayed.

FIG. 5 shows another embodiment of the present invention. A molecular arrangement and a polarizing direction of the polarizing plate are the same as FIG. 2. The width of the comb-shaped electrode 2 is larger than that of a portion without the comb-shaped electrode. When a voltage is applied between the comb-shaped electrodes having a structure of FIG. 5, a line of electric force as shown in FIG. 6 is generated. FIG. 6 shows a case where P type nematic liquid crystals or P type dichroic nematic liquid crystals are used. The liquid crystal molecules are orientated to a direction of the line of electric force. The dichroic dye molecules are also orientated perpendicular to the substrate as the liquid crystal molecules. As a result, the same display as in FIG. 4b is possible. FIG. 7 shows a case where n type nematic liquid crystals or n type dichroic nematic liquid crystals are used instead of the P type liquid crystals of FIG. 6. When a voltage is applied between the comb-shaped electrodes, the n type liquid crystal molecules are rearranged as shown in the figure. Similarly, the dye molecules are also rearranged parallel to the substrate surface. As a result, the same display as in FIG. 3b is possible as described in the explanation of FIG. 3a.

FIG. 8 and FIG. 9 show another embodiment of the present invention. An orientation treatment is performed on top and bottom substrates 1 and 5 so that a molecular arrangement is formed in which it is parallel to the substrate surface and a long axis of the liquid crystal molecules 6 is at right angle to a longitudinal direction of the comb-shaped electrode 2 on the top substrate surface, and it is perpendicular to the substrate surface on the bottom substrate surface. The polarizing plate has a polarizing direction to the paper surface direction. FIG. 8 shows a case of P type nematic liquid crystals 6 or P type dichroic nematic liquid crystals 6. When a voltage is applied between the comb-shaped electrodes, they are rearranged as in FIG. 3a and the same display as in FIG. 3b is possible. FIG. 9 shows a case where n type nematic

liquid crystals or n type dichroic nematic liquid crystals are used. When a voltage is applied between the comb-shaped electrodes, they are rearranged as in FIG. 4a and the same display as in FIG. 4b is possible.

FIG. 10 and FIG. 11 show another embodiment of the present invention. They show a case where the same molecular orientation as in FIG. 8 and FIG. 9 is formed and the width of the comb-shaped electrode is larger than that between the comb-shaped electrodes. FIG. 10 shows a case where P type liquid crystals are used and the same display as in FIG. 4b is possible. FIG. 11 shows a case where n type liquid crystals are used and the same display as in FIG. 3b is possible.

FIG. 12 shows another embodiment of the present invention.

P type liquid crystal molecules are perpendicular to the substrate surface on the top substrate surface while the liquid crystal molecules are parallel to the substrate surface and a long axis of the molecules is orientated to a longitudinal direction of the comb-shaped electrode on the bottom substrate surface. The polarizing plate polarizes light to the paper surface direction. When a voltage is not applied between the comb-shaped electrodes, polarized components of the incident light that are parallel to the paper surface correspond to a molecular minor axis direction of the dichroic dyes, and thus, they are not absorbed by the dyes. Since they are polarized to the same direction as the polarizing plate, they are transmitted through the polarizing plate, reflected by the reflector and transmitted through the polarizing plate and the liquid crystal layer again. On the other hand, light of the polarized components that are perpendicular to the paper surface is absorbed by the dyes; however, they are orthogonal to the polarizing plate, and thus they do not reach the reflector and do not return from the liquid crystal cell.

Light which returns from the liquid crystal cell is not colored since it includes all wavelengths. When a voltage is applied between the comb-shaped electrodes, the same molecular rearrangement as in FIG. 3a is generated since P type liquid crystal molecules are used, and a portion 21 with the comb-shaped electrode is strongly colored as described in the explanation of FIG. 3a, as shown in FIG. 12b. The colored portion is clearly distinguished from an uncolored portion 22 without the comb-shaped

electrode, and thus information can be displayed.

FIG. 13 shows another embodiment of the present invention.

The same molecular arrangement as in FIG. 12a is formed. The polarizing plate has a polarizing direction that is perpendicular to the paper surface. The width of the comb-shaped electrode is made larger than that between the comb-shaped electrodes, and n type liquid crystals are used. When a voltage is applied between the comb-shaped electrodes, the liquid crystal molecules and the dichroic dye molecules are rearranged to a perpendicular direction to the paper surface. As a result, the same display as in FIG. 3b is possible.

FIG. 14 shows another embodiment of the present invention. It is a case where the same molecular arrangement as in FIG. 13 is formed and P type liquid crystals are sealed. When a voltage is applied between the comb-shaped electrodes, molecules are rearranged as shown in the figure, and thus the same display as in FIG. 4b is possible.

FIG. 15 shows another embodiment of the present invention.

The liquid crystal molecules are parallel to the substrate surface and correspond to the longitudinal direction of the comb-shaped electrode on the top substrate surface, while they are perpendicular to the substrate surface on the bottom substrate surface. The polarizing plate polarizes light parallel to the paper surface. It is a case of using P type liquid crystals and the same display as in FIG. 12b is possible.

FIG. 16 and FIG. 17 show another embodiment of the present invention. The same molecular arrangement as in FIG. 15 is formed. The width of the comb-shaped electrode is larger than that between the comb-shaped electrodes. The polarizing plate is perpendicular to the paper surface. FIG. 16 shows a case of using n type liquid crystals and the same display as in FIG. 3b is possible. FIG. 17 shows a case where P type liquid crystals are used and the same display as in FIG. 4b is possible.

As described above, according to the present invention, liquid crystals can be driven by electrodes formed on one substrate and color display can be performed. Moreover, color display of the present invention provides a high-quality display. In

addition, positioning of opposed electrodes of top and bottom substrates is not needed so that an assembly work of the liquid crystal cell is simplified. Therefore, components are priced moderately and the cost needed for assembly becomes also lower, and thus, it is easier to lower the price of the device.

Note that the embodiments described above are all reflective types using a reflector; however, it can be also applied as a transmissive type without a reflector.

4. Brief Description of the Drawings

FIG. 1 shows a liquid crystal display device with conventional comb-shaped electrodes wherein FIG. 1a is a plan view thereof and FIG. 1b is a cross-sectional view thereof. FIG. 2 to FIG. 17 show one embodiment of a liquid crystal color display device according to the present invention wherein FIG. 2 is a cross-sectional view thereof, FIG. 3a is a cross-sectional view when a voltage is applied, FIG. 3b is a figure describing optical operation, FIG. 4a is a cross-sectional view showing another embodiment, FIG. 4b is a figure describing optical operation of FIG. 4a, FIG. 5 is a cross-sectional view of another embodiment, FIG. 6 is a cross-sectional view of a case where a voltage is applied to FIG. 5, FIG. 7 is a cross-sectional view showing a variation of FIG. 6, FIGS. 8, 9, 10 and 11 are cross-sectional views showing other embodiments, FIG. 12a is a cross-sectional view of another embodiment and FIG. 12b is a figure describing its optical operation. FIGS. 13, 14, 15, 16 and 17 are cross-sectional views of other embodiments.

1, 5 ··· Substrate
2 ··· Comb-shaped electrode
6 ··· Liquid crystal molecule
7 ··· Dichroic dye molecule
8 ··· Polarizing plate
9 ··· Reflector
16 ··· Line of electric force

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